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Yield Gains and Losses in Apple Trees Grown near Natural Shelter

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Summary

Three model apple orchards at Luddington EHS were each completely surrounded by shelter trees. One of the compounds was formed by cupressocyparis leylandii, another by Alnus incana and the third by an alternating mixture of each species. Cox's orange pippen, grafted on rootstock M9, were grown in the sheltered orchards and in adjoining control plots. The marketable yield in the control plots averaged 29.3 kg per tree while in the compounds the yields ranged systematically from around 20 kg close to the shelter trees to around 35 kg near the centre of the compound and away from the shelter trees.

The low yield close to the shelter trees is attributed to a large reduction in light levels and the large yield away from the shelter is attributed to reduced wind speeds with little reduction in light levels and perhaps reduced soil moisture competition from the shelter trees.

The relationship Y = 18.1 + 1.3 D where Y = Marketable Yield (kg) and D = distance to the nearest shelter tree (m) accounts for 59% of the yield variability.

Introduction

The benefits to be gained by sheltering top fruit from the wind have been reviewed in several papers (ie Waister, 1972; Starr, 1982). There are, however, disadvantages to planting in the close proximity of a natural shelter belt. Primarily a yield reduction can be expected through competition for light and soil moisture, and to a lesser extent problems may be encountered in variable pollinating insect activity and attack by pathogens and bacteria (near heavy shelter particularly). The various factors are all directly related to the distance from the shelter belt, but it has not been possible to isolate their relative contributions. For this study it has been assumed that 1) the effects of any soil moisture competition between the fruit trees and the shelter trees will be offset by reduced evaporation rates in the sheltered compounds, thus giving improved soil moisture levels (Marshall, 1967) and 2) fruit losses due to attack by pests and diseases were minimised with an integrated spray programme.

The loss of light caused by shelter belts is recognised as being of fundamental importance (MAFF, 1979). This loss can now be determined for any given location near a shelter belt using a method devised by Sparks (1978) and further developed by Wass (1982).

Field experiments which illustrate the general pattern of top-fruit yields behind shelter belts have been published by Van Rhee (1959), see fig 1a. The expected wind speed pattern near to shelter belts is illustrated by Naegeli (1953), see fig 1b.

Design and Method

The site plan of the three model orchards is given in figure 2, and the calculated light loss at 1.2 m above ground level (average blossom height) for mid April is figure 3. Mid April is likely to be a critical time for light conditions as an increase in yield due to shelter is likely to be "felt during the formation of buds for blossom in early spring" (WMO 1964 pp104). The crop records from the orchards in 1984 show that the apple trees were in the bud burst to mouse ear development stages, around mid April. Pink bud to early blossom stages were noted on 9 May and full blossom to start of petal fall by 16 May.

It is a recognised problem in analysing yield results from a shelter study that a single years results can be misleading due to annual or seasonal variations of wind, rainfall and temperature. (Van Rhee, 1959; Mackerron, 1976). This may well be the case in the present study, but in dealing with a shelter compound, rather than an isolated belt, the effects of wind direction will be greatly reduced. In addition the apple trees which reached maturity in 1984 have since been grubbed. Wind roses and temperature data for April and May 1984 at Luddington are given in the annexe and show a very high proportion of north easterly winds and low air temperatures.

A level of quality control had to be introduced to the yield data to overcome the occasionally very large yield variations between adjacent trees, see fig 4. The variation was primarily due to extreme variability in fruit number. Trees with a low number of fruits did in part compensate by producing larger fruits, and vice versa, but the maximum yields were obtained from trees which produced a very large number of small fruits, see figures 5a and 5b. The underlying yield pattern was revealed by the following procedure:-

1. Excluding the "rogue" yields a) $\leq$15 and $\geq$50 kg in total yields
   b) $\leq$15 and $\geq$45 kg in marketable yields.

2. Separating each orchard into 3 areas a) outer rows
   b) middle section
   c) central section.

3. Calculating the mean and standard deviation for all three areas separately (areas defined in fig. 3).

4. Excluding any yield outside 90% of the distribution ($\pm$1.645 St. dev).

5. Producing one composite diagram from the average of the three orchards.

The composite diagram is shown for marketable yield in figure 4c.

Results

The composite yield data were regressed against both light loss (L) and distance from the nearest shelter tree (D) separately and together. The results are given in table 1.

TABLE 1 - Regression Analysis for Light Loss and Distance in Orchard

Regression	Correlation coefficient	Variation accounted for
a) $Y = 32.0 - 0.71\ (L)$	0.66	44%
b) $Y = 18.1 + 1.30(D)$	0.77	59%
c) $Y = 21.5 - 0.22(L) + 1.04(D)$	0.78	61%

where Y = yield per tree in kg, D in metres and L is a percentage.

The relationship between tree yield and the distance to the nearest shelter tree is approximately linear (eq. b and data from fig. 4c). The relationship between light loss and distance is non-linear and this non-linearity is reflected in the lower correlation coefficient in eq. 1. Additionally regression 'a' contains large negative residuals (fig 6a) along the southern side of the compound (as does b and c) which may suggest that the light loss here is being underestimated leading to an overestimate in yield. The negative residuals along the eastern row may be explained by the persistant cold north-easterly winds during both April and May (see Annexe). Any bias due to moisture competition would be indicated by negative residuals all around the outer edges of the orchard which is not the case.

The variation in the yield data still not accounted for in the regressions is assumed to be due to the natural variability caused by root-stock and soils.

Conclusions

Classical theory indicates that windspeeds 4m inside a shelter-belt (4m high) will be 50% to 65% of the equivalent unobstructed windspeed. Despite this reduction in windspeed the yield of the apple trees closest to the shelter trees were found to yield substantially less than the average yield from the control plots. Yield reductions of 6 kg (20%) were common place and up to 10

kg (35%) not uncommon. This suggests that the 7-17% light loss is largely responsible for the yield reduction.

Windspeeds can be expected to reach a minimum of 30-45% of the unobstructed flow value (depending on the height of measurement) between 3.2 and 4.4 h from the shelter belts forming the compound. An increasing yield towards the centre may be expected due to a) decreasing windspeeds and b) decreasing light losses which reach a minimum of 2.9% at the centre. Both these factors are direct functions of distance from the nearest shelter tree and their net effect is given by the relationship $Y = 18.1 - 1.3(D)$. Their individual effects cannot be determined as the variations in yield due to variation in rootstock and soils is large, even following the quality control procedures. This accounts for the major part of the 41% of the variability remaining. No influence due to moisture competition could be identified.

Any comments or suggestions should be referred to the authors.

Keywords: Windbreaks, Shelter, Apple Yields, Light Loss.

Met Unit and Met Unit
MAFF MAFF
Wolverhampton Bristol
April 1986

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W M O	1964	Windbreaks and shelter belts. Technical Note No. 59, Geneva.

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FIG 1a Relative Yield of Apples behind a Shelter Belt (van Rhee, 1959)

all varieties averaged in each year, then averaged 1952-58 – gives 38 yield years

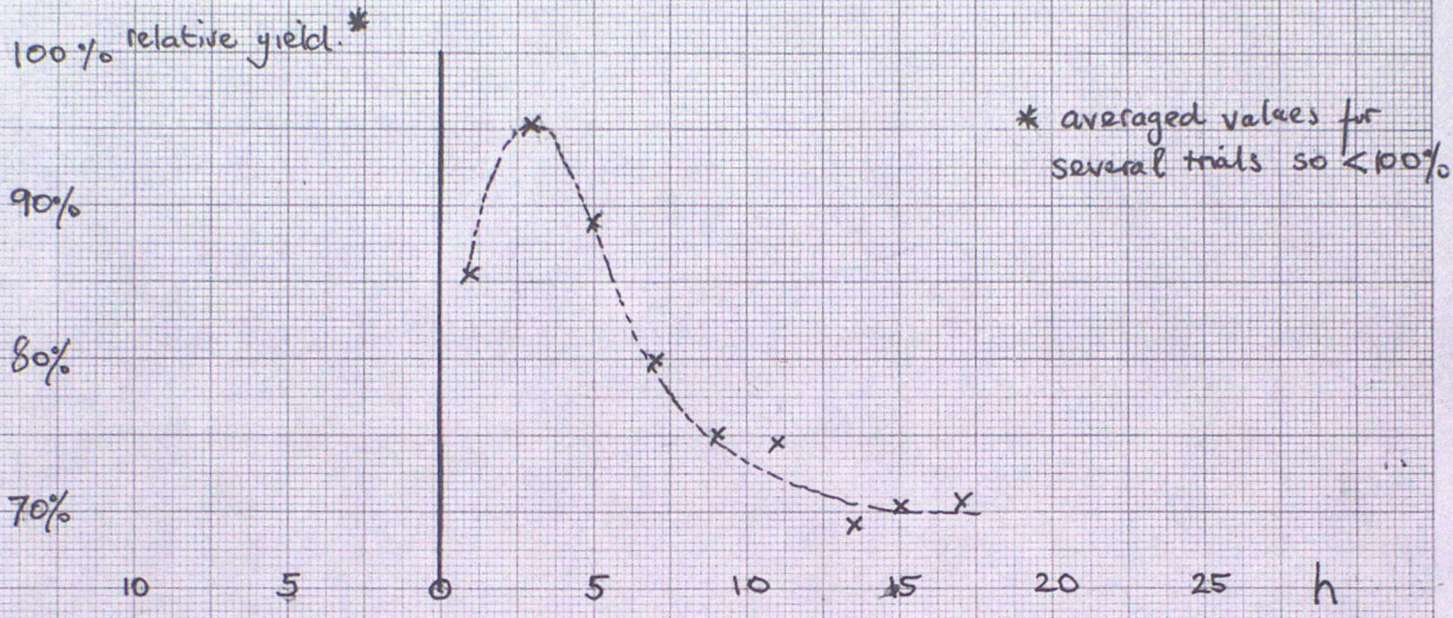
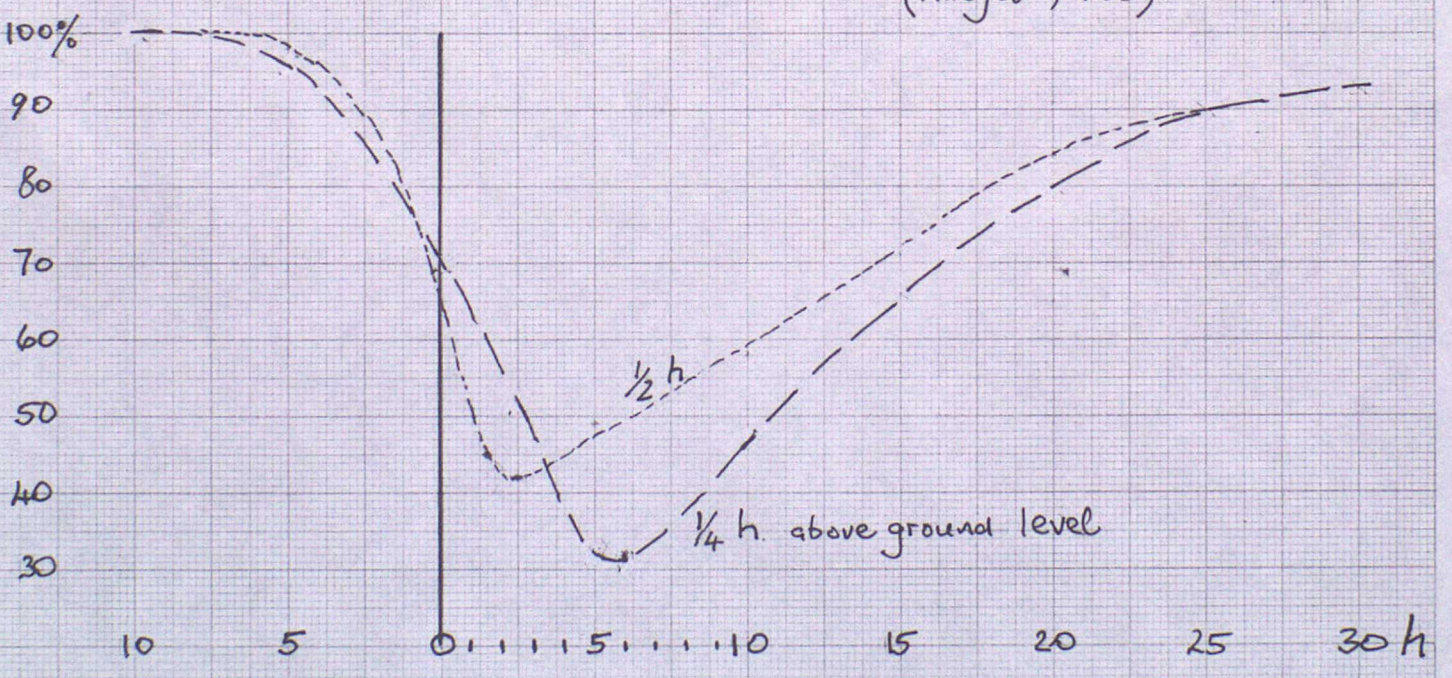


Fig 1b. Relative Windspeeds behind a 45–55% Permeable Shelterbelt.

(Naegeli, 1953)



h = height of shelter belt.

Fig. 2. Site plan of Model Orchards: Luddington EHS.
shelter trees 4m high.

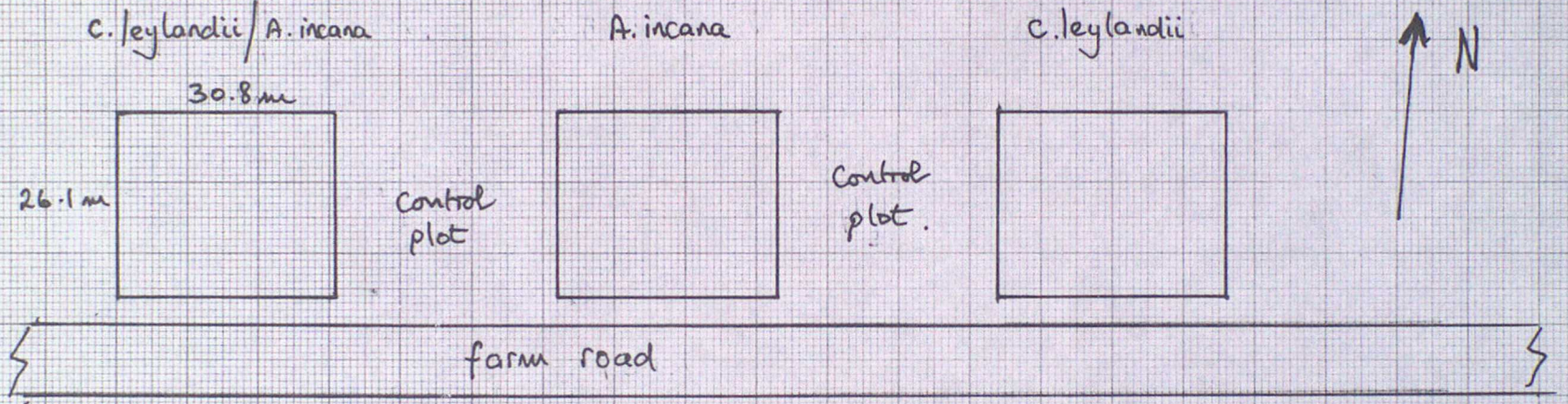
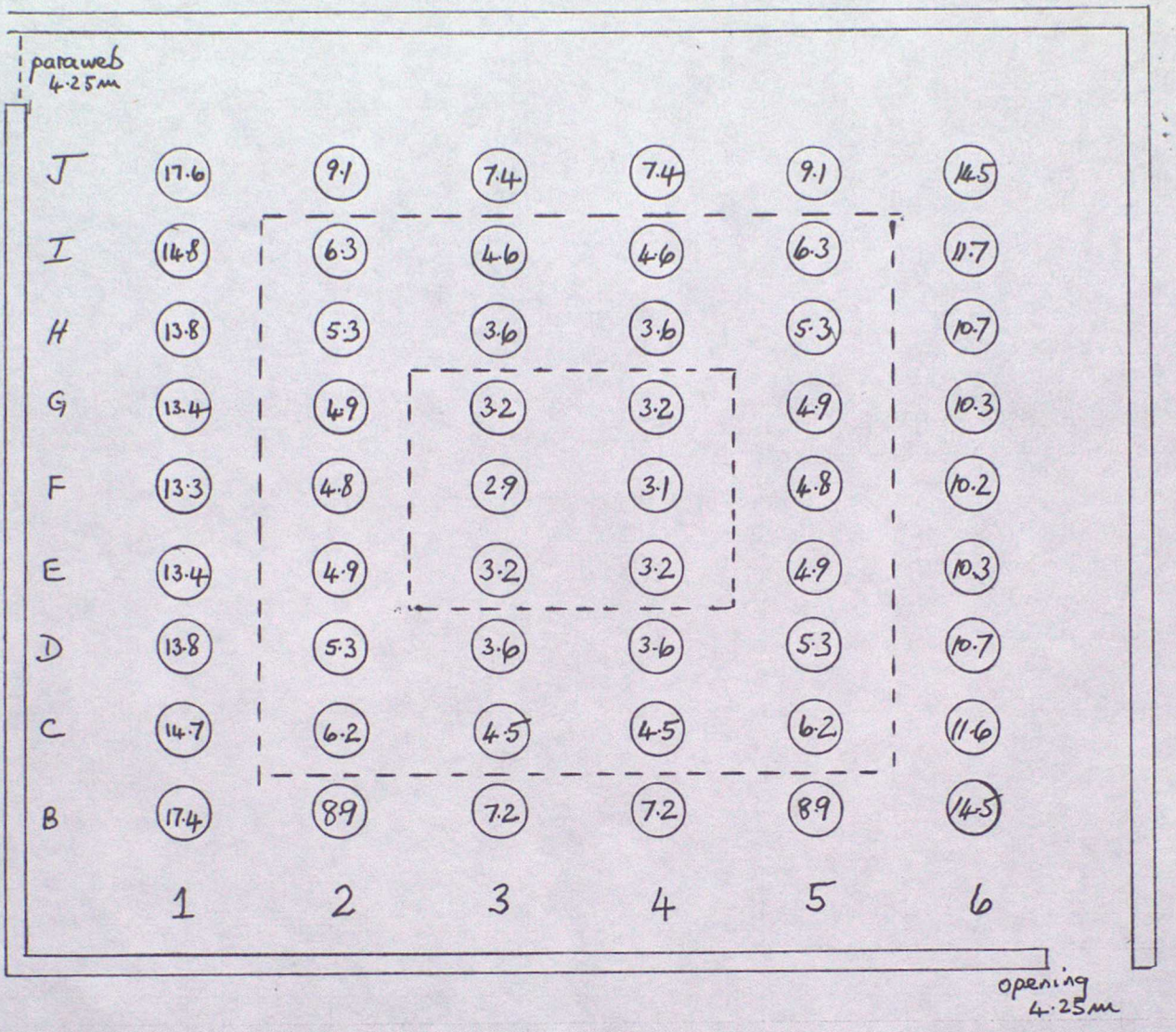


FIG. 3 PERCENT LIGHT LOSS FOR MID APRIL (1.2 m above ground)



6 rows of 9 trees; 4.4 m between rows
2.2 m between trees

lines D & H are pollinators.

The pecked lines define the areas for yield quality control.

FIG 4 MARKETABLE YIELD PER TREE (kg) FOR 3 ORCHARDS, AND "COMPOSITE" YIELD

** = rogue
* = rejected
X = pollinator

(1)

20	23	32	32	17	26
22	25	24	18*	41*	20
X	X	X	X	X	X
32	30	32	28	29	19
35*	23	25	21*	26	30
26	28	31	14**	29	37*
X	X	X	X	X	X
21	25	27	27	26	25
21	24	12**	22	27	24

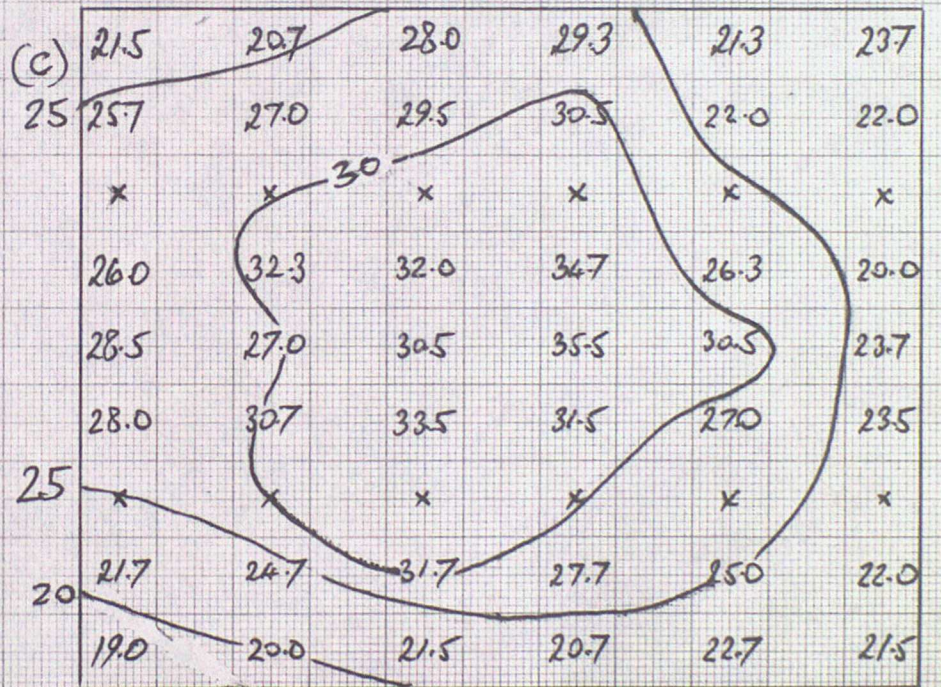
(2)

23	23	24	28	18	22
32	29	35	29	22	22
X	X	X	X	X	X
18	37	32	39	30	17
30	31	36	36	15*	21
30	33	36	38	22	25
X	X	X	X	X	X
24	28	34	29	24	21
17	-	15	15	21	19

(3)

9**	16	35*	28	29	23
23	39*	2**	32	1**	24
X	X	X	X	X	X
28	30	32	37	20	24
27	14**	9**	35	35	20
39*	31	49**	25	30	22
X	X	X	X	X	X
20	21	34	27	25	20
13**	16	28	25	20	8**

(c)



21.5	20.7	28.0	29.3	21.3	23.7
25.7	27.0	29.5	30.5	22.0	22.0
X	X	X	X	X	X
26.0	32.3	32.0	34.7	26.3	20.0
28.5	27.0	30.5	35.5	30.5	23.7
28.0	30.7	33.5	31.5	27.0	23.5
X	X	X	X	X	X
21.7	24.7	31.7	27.7	25.0	22.0
19.0	20.0	21.5	20.7	22.7	21.5

FIG 5a EFFECT OF FRUIT NUMBER ON FRUIT SIZE: 1984.

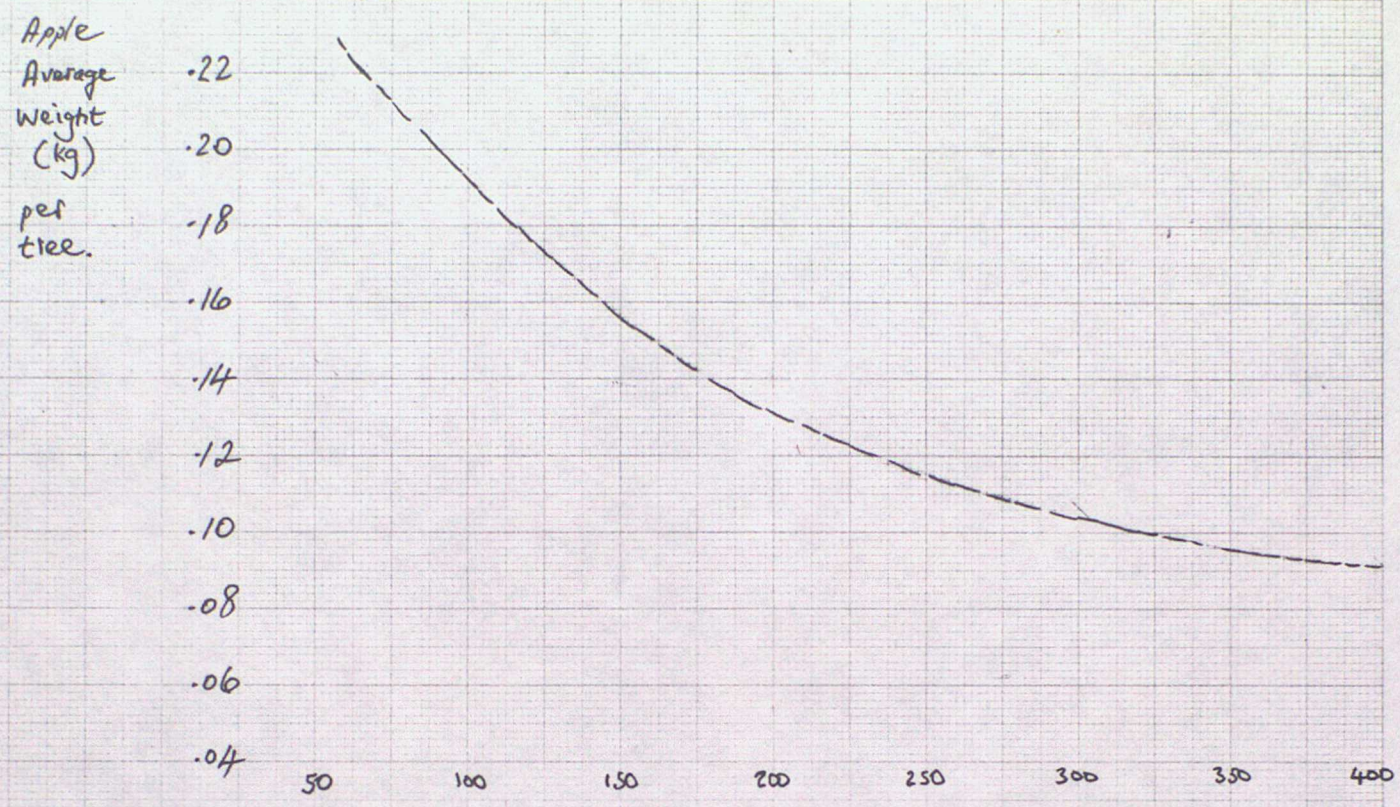


FIG 5b EFFECT OF FRUIT NUMBER ON MARKETABLE YIELD PER TREE: 1984.

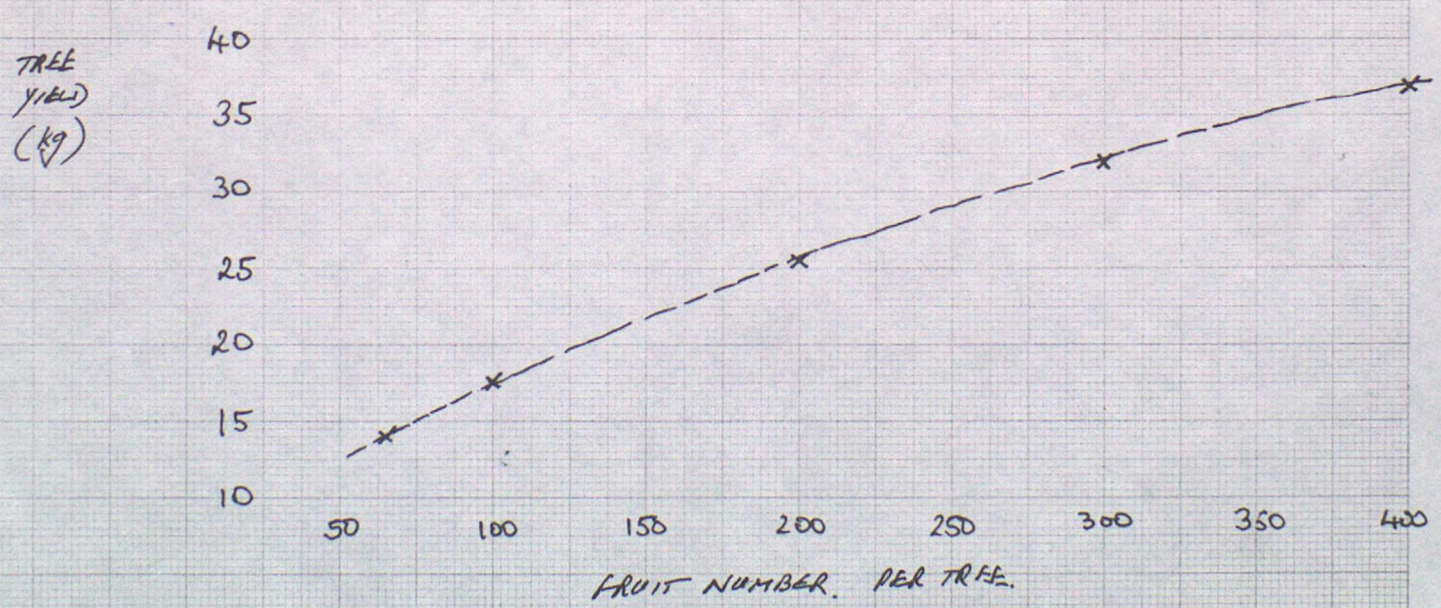
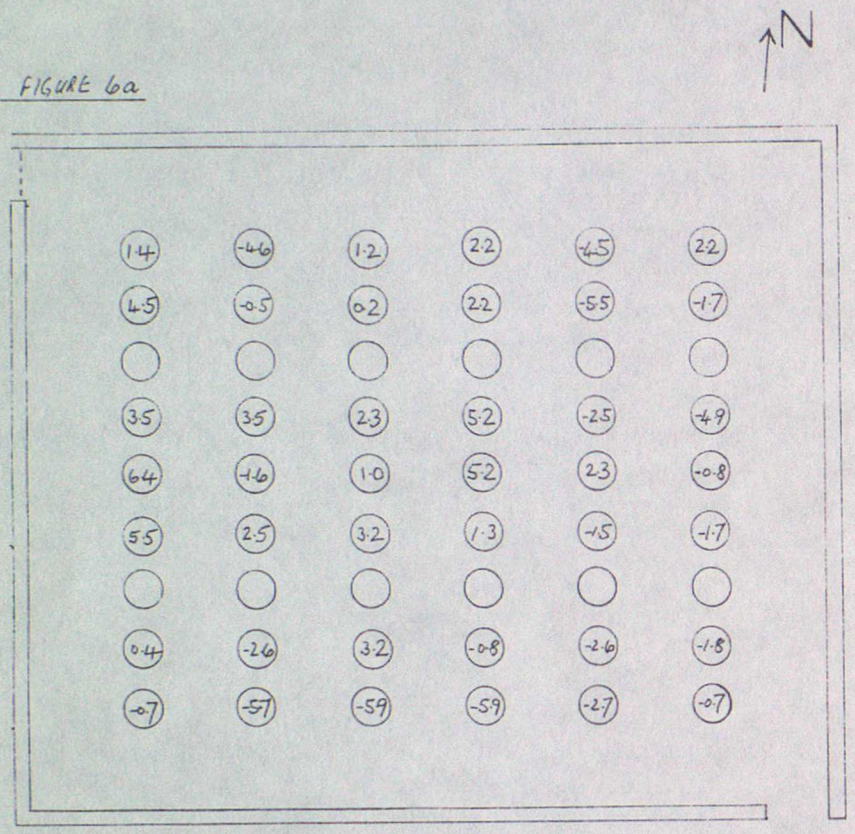


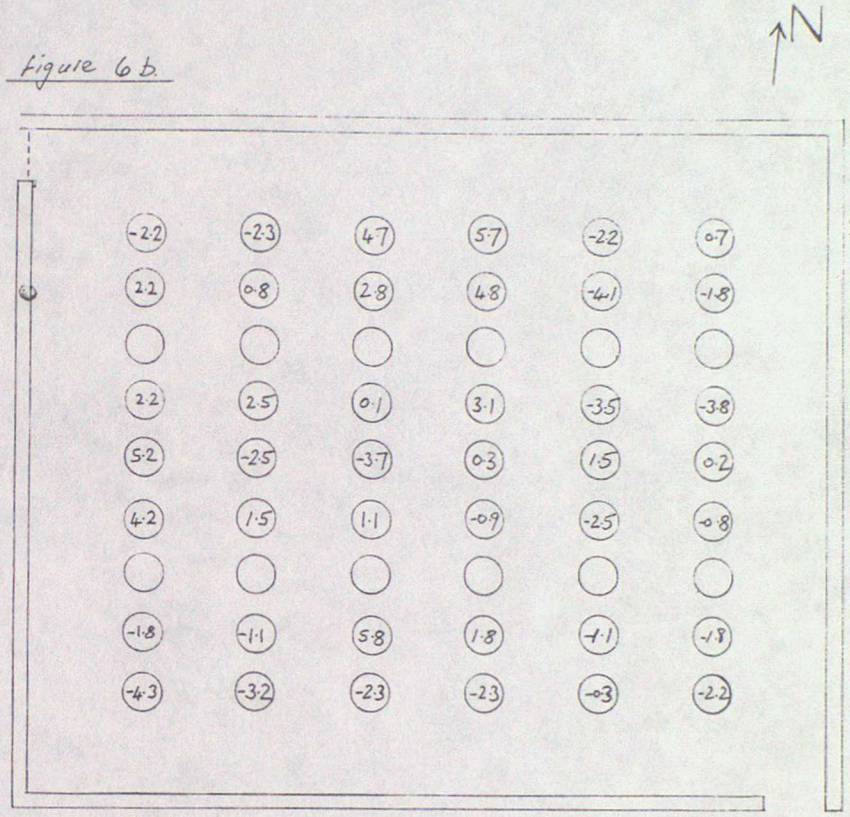
Fig. 6 Residuals from Yield Regressions.

FIGURE 6a



Residuals from regression $y = 32.0 - 0.71(L)$ $r = 0.66$ $r^2 = 0.44$

Figure 6b.

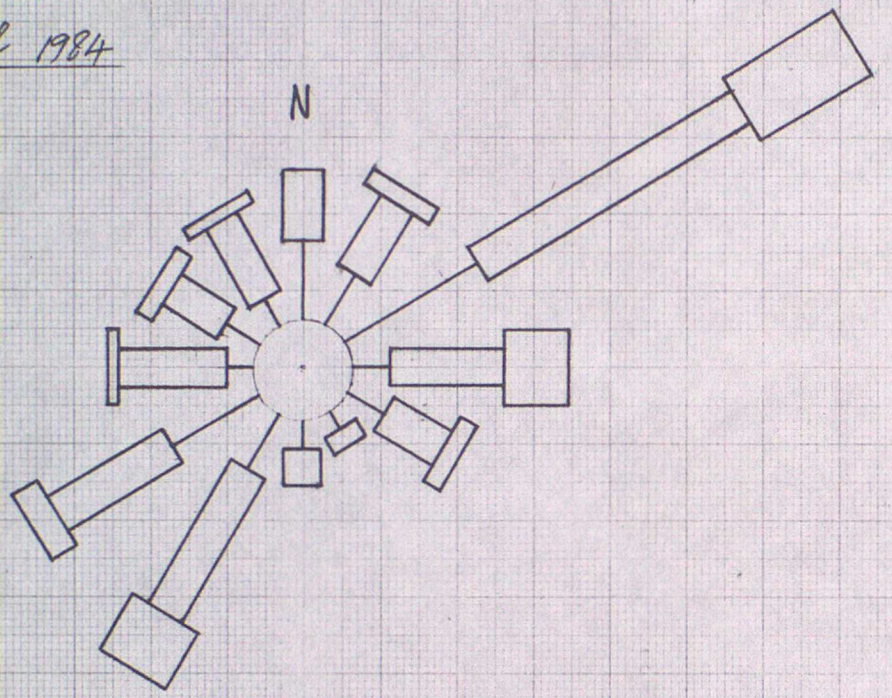


Residuals from regression $y = 18.1 + 1.30(D)$ $r = 0.77$ $r^2 = 0.59$

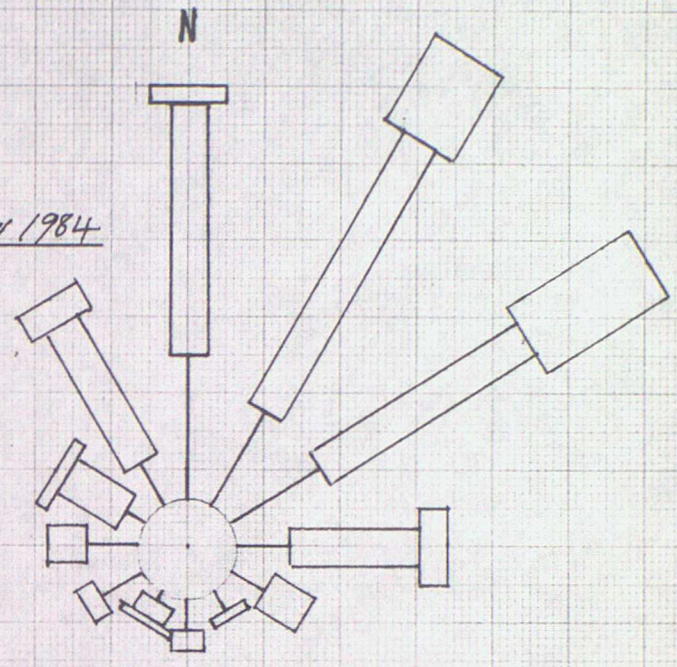
Wind Speed and Direction Frequencies : Ludlington 1984

ANNEXE

April 1984

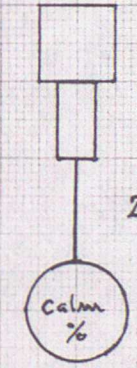


May 1984



Key

30mm = 10%



Spring Temperatures : Ludlington 1984. (°c)

	mean max	mean min	mean temp.	air frosts
March	7.6 (-2.3)	1.5 (-0.2)	4.6 (-1.2)	6
April	13.8 (-0.4)	2.1 (-1.7)	7.9 (-0.8)	9
May	14.7 (-1.9)	7.9 (-0.8)	9.8 (-1.7)	1